

FILMS PREPARED FROM PLASTICIZED POLYESTERSCROSS REFERENCE TO RELATED APPLICATIONS

5 This application claims the benefit of United States Provisional
Application Serial No. 60/282,996 filed April 11, 2001.

TECHNICAL FIELD OF THE INVENTION

10 This invention relates to the preparation of flexible films or sheets
from plasticized polyester compositions. More particularly, this invention
relates to the preparation of such films or sheets that undergo induced
crystallization, such as via calendering.

BACKGROUND OF THE INVENTION

15 Certain polymeric materials such as poly(vinyl chloride) (PVC) and
cellulose esters such as cellulose acetate, cellulose acetate propionate and
cellulose acetate butyrate must be plasticized to be processed into molded
or extruded objects. Most other thermoplastic resins such as polyesters,
polyamides and polyolefins do not typically contain a plasticizer when
20 processed in the molten state to form rigid molded or extruded objects.
However, the use of plasticizers in polyester compositions has been
disclosed for various applications.

25 U.S. Patent No. 4,450,250 to McConnell et al. describes adhesive
compositions based on amorphous or crystallizable polyesters having a
melting point in the range of 80 to 230°C containing 1 to 35 weight percent
of selected plasticizers.

U.S. Patent No. 4,340,526 to Petke et al. describes hot melt
adhesive compositions based on certain terephthalate and 1,4-
cyclohexanedicarboxylate polyesters containing 10 to 35 weight percent of
benzoate or phthalate plasticizers. The plasticizers are present to lower the

melt viscosity of the polyesters in order to facilitate their use as hot melt adhesives.

Japan Patent No. 02 986197 to Kiyomi et al. describes extruded flat or tubular film based on polyesters plasticized with 1 to 40 parts of several types of plasticizer per 100 parts of polyester, i.e. up to 28 weight percent plasticizer in overall composition. Many of the plasticizers cited are of an aliphatic nature. The films are used as shrink films.

U.S. Patent No. 5,624,987 to Brink et al. describes polyester compositions comprising a blend of poly(1,4-cyclohexylenedimethylene terephthalate) (PCT) copolyesters containing at least 80 mole percent of 1,4-cyclohexanedimethanol (CHDM) and 0.5 to 25 weight percent of one or more polyalkylene ethers. These ethers decrease the glass transition temperature (T_g) of the polyester, increase the rate of crystallization and allow the use of low molding temperatures.

U.S. Patent No. 5,824,398 to Shih describes heat shrinkable film or sheet comprising 90 to 99 weight percent of a polyester having a T_g in the range of 40 to 150°C and comprising at least 80 mole percent of aromatic dicarboxylic acids having 8 to 14 carbon atoms and at least 10 mole percent CHDM and 1 to 10 weight percent of a monoglyceride having 5 to 35 carbon atoms. The monoglyceride lowers the T_g of the blend.

U.S. Patent No. 4,391,938 to Memon describes polyethylene terephthalate (PET) compositions containing 1 to 10 weight percent of an additive to improve the crystallization rate of the polyester and to improve the surface appearance of molded parts. Additives include certain plasticizers, fast crystallizing polyesters such as poly(butylene terephthalate) (PBT), glass fibers and talc, which would act as a nucleation agent in PET.

Anonymous Research Disclosure 23314, September 1983, describes polyester compositions having improved gas barrier properties for use in making film or sheet. The polyesters contain 80 to 99 weight percent

of a homo or copolyester containing an aromatic dicarboxylic acid such as terephthalic acid and one or more glycols containing 2 to 12 carbon atoms and 1 to 20 weight percent of benzoic acid esters or phthalic acid esters.

5 Great Britain Patent No. 815,991 to Goodale et al. describes a process for making dibenzoate esters from glycols and butyl benzoate using a calcium oxide ester exchange catalyst. These esters are reported to be plasticizers for PVC resins.

10 U.S. Patent No. 3,186,961 to Sears describes polycarbonate resins plasticized with a wide range of plasticizers. The molten blends must be quenched to achieve the desired properties. The presence of the plasticizer increases the rate of crystallization of the polycarbonate.

15 U.S. Patent No. 2,044,612 to Jaeger describes plasticizers for several polymeric materials such as cellulose esters, phenol/formaldehyde resins, urea resins and the like.

20 Great Britain 1,323,478 (1973) assigned to Stamicarbon N.V. describes the preparation of dibenzoate plasticizers for use in PVC and poly(vinyl acetate) compositions

25 In the manufacture of film and sheet, processes such as calendering and extrusion are used to produce film and sheet from a wide variety of plastics. Calendering in particular is used to produce film and sheet from plastics such as plasticized and rigid PVC compositions. On a smaller scale, other thermoplastic polymers such as thermoplastic rubbers, certain polyurethanes, talc-filled polypropylene, acrylonitrile/butadiene/styrene terpolymers (ABS resins) and chlorinated polyethylene are sometimes
30 processed by calendering methods. U.S. Patent No. 6,068,910 to Flynn et al. discloses the feasibility of calendering certain polyesters having a crystallization half time from the molten state of at least 5 minutes to provide film and sheet. Although this patent recognized the need for processing aids to prevent molten polymer from sticking to the calender rolls, large concentrations of plasticizers were not used.

BRIEF SUMMARY OF THE INVENTION

A process for preparing a film or sheet having a glass transition temperature below about 23°C and a melting temperature greater than about 120°C comprises the steps of:

- 5 (a) preparing a polyester composition comprising
 - (i) about 50 to about 95 weight percent of a base copolyester having a melting temperature of less than about 220°C and exhibiting more than 1 percent crystallinity after annealing for 2000 minutes at a temperature of which the base copolyester has a maximum crystallization rate, and
 - 10 (ii) about 5 to about 50 weight percent of a plasticizer suitable for use with the base copolyester;
- (b) forming the polyester composition into a film or sheet; and
- (c) inducing crystallization during step (b) or after step (b).

- 15 In another embodiment, a film or sheet has a glass transition temperature below about 23°C and a melting temperature greater than about 120°C and comprises a polyester composition comprising
 - (a) about 50 to about 95 weight percent of a base copolyester having a melting temperature of less than about 220°C and exhibiting more
 - 20 than 1 percent crystallinity after annealing for 2000 minutes at a temperature of which the base copolyester has a maximum crystallization rate and
 - (b) about 5 to about 50 weight percent of a plasticizer suitable for use with the base copolyester.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a dynamic mechanical analysis, DMTA, curve of Examples 1 to 4.

Figure 2 is a DMTA curve of Examples 5 to 8.

30 Figure 3 is a DMTA curve of Examples 9 to 12.

DETAILED DESCRIPTION OF THE INVENTION

This invention relates to a process for preparing a film or sheet from a plasticized polyester composition. Unexpectedly the film or sheet formed is soft and flexible having a glass transition temperature (T_g) below about 23°C, preferably below about 0°C, and a crystalline melting point (T_m) above about 120°C, preferably above about 140°C. To obtain such a film or sheet the plasticized polyester composition undergoes induced crystallization either during or after the formation of the film or sheet. More specifically, the process for preparing the film or sheet of the present invention comprises the steps of:

- (a) preparing the polyester composition that comprises a base copolyester and a plasticizer;
- (b) forming the polyester composition into a film or sheet; and
- (c) inducing crystallization during step (b) or after step (b).

The polyester composition comprises about 50 to about 95 weight percent, preferably about 50 to about 80 weight percent and more preferably about 60 to about 75 weight percent, of the base copolyester and about 5 to about 50 weight percent, preferably about 20 to about 50 weight percent and more preferably about 25 to about 40 weight percent, of the plasticizer or combination of plasticizers suitable for use with the base copolyester. The base copolyester has a melting temperature of less than about 220°C and exhibits more than about 1 percent crystallinity after annealing for 2000 minutes at a temperature of which the base copolyester has a maximum crystallization rate.

The base copolyester of the polyester composition preferably comprises (i) a diacid component comprising residues of at least about 80 mole percent of a primary diacid selected from terephthalic acid, naphthalenedicarboxylic acid, 1,4-cyclohexanedicarboxylic acid, isophthalic acid or mixtures thereof and (ii) a diol component comprising residues of at least about 80 mole percent of at least one primary diol containing 2 to

about 10 carbon atoms. The diacid component is based on 100 mole percent and the diol component is based on 100 mole percent.

Any of the various isomers of naphthalenedicarboxylic acid or mixtures of isomers may be used but the 1,4-, 1,5-, 2,6- and 2,7- isomers are preferred. Also, cis, trans or cis/trans isomer mixtures of 1,4-cyclohexanedicarboxylic acid may be used. The diacid component may be modified with up to about 20 mole percent of a modifying diacid containing from about 4 to about 40 carbon atoms, such as succinic acid, glutaric acid, adipic acid, suberic acid, sebacic acid, azelaic acid, dimer acid, sulfoisophthalic acid or mixtures thereof.

For the diol component of the base copolyester, the preferred primary diol includes ethylene glycol, diethylene glycol, neopentyl glycol, 1,4-cyclohexanedimethanol or mixtures thereof. More preferably, the primary diol comprises residues of from about 10 to 100 mole percent 1,4-cyclohexanedimethanol (CHDM) and from about 90 to 0 mole percent ethylene glycol. Even, more preferably, the primary diol comprises residues of from about 10 to about 40 mole percent CHDM and from about 90 to about 60 mole percent ethylene glycol. The diol residue component may also be modified with up to about 20 mole percent of other diols. Suitable modifying diols include 1,3-propanediol, propylene glycol, 1,4-butanediol, 1,5-pentanediol, 1,6-hexanediol, 1,8-octanediol, 2,2,4-trimethyl-1,3-pentanediol, 2,2,4,4-tetramethyl-1,3-cyclobutanediol, 1,3-CHDM or mixtures thereof. Also small amounts of polyalkylene glycols such as polyethylene glycol, polypropylene glycol, and polytetramethylene glycol may be used if desired. The CHDM moiety may be as the cis, trans or cis/trans mixture of isomers.

Sometimes the melt viscosity and melt strength of the base copolyester are insufficient for suitable processing on calendering equipment. In these cases, the use of a melt strength enhancer is desirable such as by the addition of small amounts (about 0.1 to about 2.0 mole

percent) of a branching agent to the copolyester either during their initial preparation or during subsequent blending or feeding procedures prior to reaching the calendering equipment. Suitable branching agents include multifunctional acids or alcohols such as trimellitic acid, trimellitic anhydride, pyromellitic dianhydride, trimethylolpropane, glycerol, pentaerythritol, citric acid, tartaric acid, and 3-hydroxyglutaric acid. These branching agents may be added directly to the copolyester or blended with the copolyester in the form of a concentrate as described in U.S. Pat. Nos. 5,654,347 and 5,696,176. It is also possible to use agents such as sulfoisophthalic acid to increase the melt strength of the polyester to a desirable level as disclosed in U.S. Pat. No. 5,399,595.

The copolyesters used in the present invention are readily prepared by melt phase techniques well known in the art. In addition, some of the copolyesters may be made by a combination of melt phase and solid phase polycondensation procedures also well known in the art. The inherent viscosity, IV, of useful polyesters will generally range from about 0.4 to about 1.5 dL/g and preferably about 0.6 to about 1.2 dL/g. IV measurements are generally made at 25°C using 0.50 gram of polymer in 100 mL of a solvent composed of 60 weight percent phenol and 40 weight percent 1,1,2,2-tetrachloroethane.

The plasticizer for use in the present invention should be suitable for use with the copolyester. The presence of the plasticizer is quite beneficial to lower the processing temperature of the polyester, to prevent sticking to the rolls, to eliminate predrying of the polyester and to create elastomeric materials having good mechanical properties. The preferred range of plasticizer content will depend on the properties of the base polyester and the plasticizer. In particular, the lower the Tg of the base copolyester and/or the plasticizer as predicted by the well-known Fox equation (T.G. Fox, Bull. Am. Phys. Soc., 1, 123 (1956)), the lesser the amount of plasticizer needed to obtain the polyester composition that produces a film

or sheet having a Tg below 23°C. For the polyester compositions described in Examples 1-13, the preferred range of plasticizer content is from about 20 to about 50 weight percent and more preferably from about 25 to about 40 weight percent.

5 Preferred plasticizers dissolve a film of the polyester to produce a clear solution at temperatures below about 160°C. This property of the plasticizer is referred to as its solubility. The procedure for determining whether a plasticizer has the appropriate solubility is as follows. Materials required for the test include a standard reference film of 5 mils (.127 mm) in
10 thickness, a small vial, a heating block or oven and a plasticizer. The following steps are performed:

1. In the vial, place a piece of the film of a width of the vial and 1/2 inches long.
2. Add the plasticizer to the vial until the film is covered completely.
- 15 3. Place the vial with the film and plasticizer on a shelf to observe after one hour and again at 4 hours. Note the appearance of the film and liquid.
4. After the ambient observation, place the vial in a heating block and allow the temperature to remain constant at 75°C for one hour and
20 observe the appearance of the film and liquid.
5. Repeat step 4 for each of the following temperatures (°C): 75, 100, 140, 150, and 160.

The results of several plasticizers tested for their solubility are set forth in Table 1 below. A value of 4 or greater over the temperature indicates that
25 this plasticizer is candidate for use in the present invention.

Table 1

TEMPERATURE (°C)	23	75	100	140	150	160
Adipic Acid Derivatives						
Dicapryl adipate	1	1	1	1	2	2
Di-(2-ethylhexyl adipate)	1	1	1	1	2	2
Di(n-heptyl, n-nonyl) adipate	1	1	1	1	2	2
Diisobutyl adipate	1	3	3	3	3	4
Diisodecyl adipate	1	1	1	1	1	1
Dinonyl adipate	1	1	1	1	1	2
Di-(tridecyl) adipate	1	1	1	1	1	1
Azelaic Acid Derivatives						
Di-(2-ethylhexyl azelate)	1	1	1	1	2	2
Diisodecyl azelate	1	1	1	1	1	1
Diioctyl azelate	1	1	1	1	2	2
Dimethyl azelate	3	4	4	4	4	6
Di-n-hexyl azelate	1	1	2	2	3	3
Benzoic Acid Derivatives						
Diethylene glycol dibenzoate	4	4	4	6	6	6
Dipropylene glycol dibenzoate	3	3	4	4	4	6
Propylene glycol dibenzoate	1	3	4	6	6	6
Polyethylene glycol 200 dibenzoate	4	4	4	4	6	6
Neopentyl glycol dibenzoate	0	3	3	3	4	6
Citric Acid Derivatives						
Acetyl tri-n-butyl citrate	1	1	1	2	3	3
Acetyl triethyl citrate	1	2	2	2	3	3
Tri-n-Butyl citrate	1	2	3	3	3	3
Triethyl citrate	3	3	3	3	3	3
Dimer Acid Derivatives						
Bis-(2-hydroxyethyl dimerate)	1	1	1	1	2	3
Epoxy Derivatives						
Epoxidized linseed oil	1	2	2	2	3	3
Epoxidized soy bean oil	1	1	1	1	1	2

2-Ethylhexyl epoxytallate	1	1	1	1	3	3
Fumaric Acid Derivatives						
Dibutyl fumarate	2	2	3	3	3	3
Glycerol Derivatives						
Glycerol Tribenzoate	0	0	6	6	6	6
Glycerol triacetate	2	3	3	3	3	4
Glycerol diacetate monolaurate	1	2	2	2	2	4
Isobutyrate Derivative						
2,2,4-Trimethyl-1,3-pentanediol, Diisobutyrate	1	1	1	1	3	3
Texanol diisobutyrate	1	2	2	2	2	4
Isophthalic Acid Derivatives						
Dimethyl isophthalate	0	5	5	6	6	6
Diphenyl isophthalate	0	0	0	0	0	0
Di-n-butylphthalate	2	3	3	3	3	3
Lauric Acid Derivatives						
Methyl laurate	1	2	3	3	3	3
Linoleic Acid Derivative						
Methyl linoleate, 75%	1	1	2	3	3	3
Maleic Acid Derivatives						
Di-(2-ethylhexyl) maleate	1	1	2	3	3	3
Di-n-butyl maleate	2	3	3	3	3	3
Mellitates						
Tricapryl trimellitate	1	1	1	1	1	1
Triisodecyl trimellitate	1	1	1	1	1	1
Tri-(n-octyl,n-decyl) trimellitate	1	1	1	1	1	1
Triisonyl trimellitate	1	1	1	1	1	1
Myristic Acid Derivatives						
Isopropyl myristate	1	1	1	2	3	3
Oleic Acid Derivatives						
Butyl oleate	1	1	1	2	3	3
Glycerol monooleate	0	1	1	1	3	3
Glycerol trioleate	1	1	1	1	2	2
Methyl oleate	1	1	2	2	3	3
n-Propyl oleate	1	1	1	2	3	3

Tetrahydrofurfuryl oleate	1	1	1	2	3	3
Palmitic Acid Derivatives						
Isopropyl palmitate	1	1	1	1	2	3
Methyl palmitate	0	1	1	2	3	3
Paraffin Derivatives						
Chloroparaffin, 41% C1	1	1	2	2	2	3
Chloroparaffin, 50% C1	1	2	3	3	3	3
Chloroparaffin, 60% C1	1	5	6	6	6	6
Chloroparaffin, 70% C1	0	0	0	0	0	0
Phosphoric Acid Derivatives						
2-Ethylhexyl diphenyl phosphate	2	3	3	3	4	4
Isodecyl diphenyl phosphate	1	2	3	3	3	3
t-Butylphenyl diphenyl phosphate	1	3	3	4	6	6
Tri-butoxyethyl phosphate	1	2	3	4	4	4
Tributyl phosphate	2	3	3	3	3	3
Tricresyl phosphate	1	3	3	4	6	6
Triphenyl phosphate	0	4	4	6	6	6
Phthalic Acid Derivatives						
Butyl benzyl phthalate	2	3	3	6	6	6
Texanol benzyl phthalate	2	2	2	2	2	4
Butyl octyl phthalate	1	1	2	2	3	3
Dicapryl phthalate	1	1	1	1	2	2
Dicyclohexyl phthalate	0	1	2	2	4	5
Di-(2-ethylhexyl) phthalate	1	1	1	2	3	3
Diethyl phthalate	4	4	4	6	6	6
Dihexyl phthalate	1	2	3	3	3	3
Diisobutyl phthalate	1	3	3	3	3	5
Diisodecyl phthalate	1	1	1	1	2	2
Diisoheptyl phthalate	1	1	2	3	3	3
Diisononyl phthalate	1	1	1	1	2	3
Diisooctyl phthalate	1	1	2	2	3	3
Dimethyl phthalate	1	5	6	6	6	6
Ditridecyl phthalate	1	1	1	1	2	3
Diundecyl phthalate	1	1	1	2	2	2

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Ricinoleic Acid Derivatives						
Butyl ricinoleate	1	1	2	3	3	3
Glycerol tri(acetyl) ricinlloate	1	1	1	2	1	1
Methyl acetyl ricinlloate	1	1	2	3	3	3
Methyl ricinlloate	1	2	3	3	3	4
n-Butyl acetyl ricinlloate	1	1	1	2	3	3
Propylene glycol ricinlloate	1	1	3	3	4	4
Sebacic Acid Derivatives						
Dibutyl sebacate	1	2	3	3	3	3
Di-(2-ethylhexyl) sebacate	1	1	1	2	2	3
Dimethyl sebacate	0	4	4	6	6	6
Stearic Acid Derivatives						
Ethylene glycol monostearate	0	1	2	3	3	3
Glycerol monostearate	0	0	1	2	2	2
Isopropyl isostearate	3	3	3	6	6	6
Methyl stearate	0	1	2	2	2	3
n-Butyl stearate	1	1	2	3	3	3
Propylene glycol monostearate	0	1	1	2	2	3
Succinic Acid Derivatives						
Diethyl succinate	3	3	4	5	6	6
Sulfonic Acid Derivatives						
N-Ethyl o,p-toluenesulfonamide	2	5	6	6	6	6
o,p-toluenesulfonamide	0	0	0	6	6	6

Key:

0 = Plasticizer is a solid at this temperature

1 = Plasticizer is liquid, yet nothing happening to the film

5 2 = film has begun to haze

3 = film has swollen

4 = film has begun to change as disintegrating off and/or liquid becoming hazy

5 = no longer a film, liquid is hazy

10 6 = liquid is clear

A similar test to that above can be referenced in "The Technology of Plasticizers", by J. Kern Sears and Joseph R. Darby, published by Society of Plastic Engineers/Wiley and Sons, New York, 1982, pp 136-137. In this test, a grain of the polymer is placed in a drop of plasticizer on a heated microscope stage. If the polymer disappears, then it is solubilized.

The plasticizers that are most effective at solubilizing the polyester have a solubility of greater than 4 according to Table 1 and can also be classified according to their solubility parameter. The solubility parameter, or square root of the cohesive energy density, of a plasticizer can be calculated by the method described by Coleman et al., *Polymer* 31, 1187 (1990), herein incorporated by reference. The most preferred plasticizers will have a solubility parameter (δ) in the range from about 9.5 to about 13.0 $\text{cal}^{0.5}\text{cm}^{-1.5}$. Table 2 demonstrates that plasticizers with a solubility parameter within this range solubilize the polyester while those plasticizers with a solubility parameter outside of this range are much less effective. In general, higher molecular weight plasticizers are preferred to prevent smoking and loss of plasticizer during the calendering process.

Table 2

Plasticizer	δ ($\text{cal}^{0.5}\text{cm}^{-1.5}$)	Solubility @ 160°C from Table 1
Glycerol diacetate monolaurate	8.1	4
Texanol diisobutyrate	8.4	4
Di-2-ethylhexyladipate	8.5	2
Trioctyltrimellitate	8.8	1
Di-2-ethylhexylphthalate	8.9	2
Texanol benzyl phthalate	9.5	4
Neopentyl glycol dibenzoate	9.8	6
Dipropylene glycol dibenzoate	10.0	6
Butyl benzyl phthalate	10.1	6

Propylene glycol dibenzoate	10.3	6
Diethylene glycol dibenzoate	10.3	6
Glycerol tribenzoate	10.6	6

Particular plasticizers suitable for use in the present invention include esters based on an acid moiety selected from phthalic acid, adipic acid, trimellitic acid, benzoic acid, azelaic acid, terephthalic acid, isophthalic acid, butyric acid, glutaric acid, citric acid and phosphoric acid. The alcohol moiety is selected from aliphatic, cycloaliphatic or aromatic alcohols containing from about 1 to about 20 carbon atoms. Suitable alcohol moieties include those based on methanol, ethanol, propanol, isopropanol, butanol, isobutanol, stearyl alcohol, lauryl alcohol, phenol, benzyl alcohol, ethylene glycol, neopentyl glycol, CHDM, and diethylene glycol.

In step (b) and (c) of the present invention the polyester composition is respectively formed into a film or sheet and crystallization is induced. Inducing crystallization may be done either during or after forming the film or sheet. In one preferred embodiment, forming of the film or sheet occurs by melt extrusion or cast extrusion and inducing crystallization occurs after forming by stretching. In another preferred embodiment, forming of the film or sheet occurs by melt extrusion or cast extrusion and inducing crystallization occurs after forming by annealing at a temperature greater than the glass transition temperature of the film and less than melting temperature of the base copolyester. In still another preferred embodiment, forming of the film or sheet and inducing crystallization occur together during step (b) by calendering or blown film extrusion.

The most preferred embodiment of the present invention is a process for preparing a film or sheet comprising the steps of:

- (a) preparing a polyester composition comprising
 - (i) about 50 to about 80 weight percent of a base copolyester having a melting temperature of less than about 220°C

and a glass transition temperature of greater than about 60°C and exhibiting more than about 1 percent crystallinity after annealing for 2000 minutes at a temperature of which the base copolyester has a maximum crystallization rate, and

5 (ii) about 20, preferably about 25, to about 50 weight percent of a plasticizer suitable for use with the base copolyester.

(b) forming the polyester composition into a film or sheet; and

(c) inducing crystallization during step (b) or after step (b);

wherein after step (c) the film or sheet has a glass transition temperature
10 below about 23°C and a melting temperature greater than about 140°C. In such a process the base copolyester preferably comprises a diacid component comprising residues of at least 80 mole percent of a primary diacid selected from the group consisting of terephthalic acid, naphthalenedicarboxylic acid, 1,4-cyclohexanedicarboxylic acid, isophthalic
15 acid and mixtures thereof and a diol component comprising residues of about 10 to about 40 mole percent 1,4-cyclohexanedimethanol and about 90 to 60 mole percent ethylene glycol, wherein the diacid component is based on 100 mole percent and the diol component is based on 100 mole percent. The plasticizer is preferably selected from the group consisting of
20 neopentyl glycol dibenzoate, diethylene glycol dibenzoate, butyl benzyl phthalate; Texanol benzyl phthalate.

In another embodiment of the present invention, a film or sheet has a glass transition temperature below about 23°C, preferably below about 0°C, and a melting temperature greater than about 120°C, preferably greater
25 than about 140°C; and comprises a polyester composition comprising (a) about 50 to about 95 weight percent of a base copolyester having a melting temperature of less than about 220°C and exhibiting more than about 1 percent crystallinity after annealing for 2000 minutes at a temperature of which the base copolyester has a maximum crystallization rate and (b)

about 50 to about 5 weight percent of a plasticizer suitable for use with the base copolyester.

Preferably, base copolyester comprises a diacid component comprising residues of at least about 80 mole percent of a primary diacid selected from the group consisting of terephthalic acid, naphthalenedicarboxylic acid, 1,4-cyclohexanedicarboxylic acid, isophthalic acid and mixtures thereof and a diol component comprising residues of at about least 80 mole percent of at least one primary diol containing 2 to about 10 carbon atoms, wherein the diacid component is based on 100 mole percent and the diol component is based on 100 mole percent.

Preferably, the plasticizer presenting the film or sheet is present in an amount of from about 20 weight percent to about 50 weight percent. The plasticizer is preferably selected from one that dissolves a 5-mil thick film of the base copolyester to produce a clear solution at a temperature below 160°C. More preferably, the plasticizer is selected from one that has a solubility parameter in the range from about 9.5 to about 13.0 cal^{0.5}cm^{-1.5}.

More preferably, base copolyester comprises a diacid component comprising residues of at least about 80 mole percent of a primary diacid selected from the group consisting of terephthalic acid, naphthalenedicarboxylic acid, 1,4-cyclohexanedicarboxylic acid, isophthalic acid and mixtures thereof and a diol component comprising residues of about 10 to about 40 mole percent 1,4-cyclohexanedimethanol and about 60 to 90 mole percent ethylene glycol, wherein the diacid component is based on 100 mole percent and the diol component is based on 100 mole percent. The plasticizer is selected from the group consisting of neopentyl glycol dibenzoate, diethylene glycol dibenzoate, butyl benzyl phthalate; and texanol benzyl phthalate.

This invention can be further illustrated by the following examples of preferred embodiments thereof, although it will be understood that these examples are included merely for purposes of illustration and are not

intended to limit the scope of the invention unless otherwise specifically indicated.

EXAMPLES

5 Examples 1-9

A polyester, which contains an acid component of 100 mole % terephthalic acid and a glycol component of 31 mole % 1,4-cyclohexanedimethanol and 69 mole % ethylene glycol and has an IV of 0.76 dL/g, a weight average molecular weight of 40400 g/mol and a T_g of about 78°C, was pre-dried at 65°C for 12 hours in a dehumidified dryer and compounded with various plasticizers, as listed in Table 3, using a 30-mm Werner-Pfleiderer 40:1 L/D co-rotating twin screw extruder. Without additional drying, the extruded compositions were then formed into films having a thickness of 0.254 mm using a 25.4-mm Killion extruder fitted with a 152-mm film die. The films were subsequently annealed in a vacuum oven at 100°C for 90 minutes. Properties of the films including T_g, T_m, and weight average molecular weight before (Comparative Examples 1-4) and after (Illustrative Examples 5-8) the annealing process are summarized in Table 3. Examples 1 to 4 display a T_g below 23°C as measured by differential scanning calorimetry, DSC, at a heating rate of 20°C/min. Examples 1-4 show no T_m. The annealed compositions, Examples 5-8, exhibit a T_g below 23°C as well as a T_m between 140°C and 170°C.

Dynamic mechanical thermal analysis, DMTA, curves of Examples 1 to 4 are presented in Figure 1. All DMTA experiments were performed at an operating frequency of 16 Hz and a heating rate of 10°C/minute. Below the onset of the T_g, the compositions possess a high modulus indicative of a rigid material. During the transition from glass to rubber, the modulus falls precipitously. This region of the DMTA curve is commonly referred to as the leathery region because of the texture and feel of the material. At the end of the glass transition region, the DMTA curves display a short plateau

that extends to between 50 and 80°C, which is followed by a drop in modulus due to viscous flow. This plateau defines the temperature regime where the composition is soft, flexible and rubber-like. Thus, the utility of Examples 1 to 4 is severely limited to a narrow range of temperatures above T_g defined by the short rubbery plateau.

DMTA curves of Examples 5 to 8 are presented in Figure 2. Below the onset of T_g, the compositions possess a modulus similar to that of the non-annealed samples. The transition from glass to rubber in the annealed samples occurs over a broader range than in the non-annealed samples.

At the end of the glass transition region, the DMTA curves display a plateau that extends to about 150°C, approximately 70°C beyond the end of the rubbery plateau for the non-annealed samples. Consequently, the utility of Examples 5 to 8 now extends well beyond that for Examples 1 to 4. These results are totally unexpected.

Table 3

	Comparative Examples				Illustrative Examples			
	1	2	3	4	5	6	7	8
Base Copolyester (wt %)	70	70	70	70	70	70	70	70
Neopentyl glycol dibenzoate (wt%)	30				30			
Diethylene glycol dibenzoate (wt%)		30				30		
Butyl Benzyl Phthalate (wt%)			30				30	
Texanol Benzyl Phthalate (wt%)				30				30
T _g (°C) by	16	-3	5	18	14	-23	-24	16

DSC								
Tm (°C) by DSC	-	-	-	-	155	145	150	155
Weight Avg. Molecular Weight by GPC (g/mol)	39000	39400	39000	38000	39000	38600	38500	39800

Example 9

The polyester composition of Example 9, with data summarized in Table 4, was prepared the same as Example 1. This example shows the properties of an extruded film that was subsequently subjected to a 3x3 biaxial stretch at 23°C to effect crystallization. The resulting film displays a Tg below 23°C and a Tm of 151°C. Both induced crystallization by annealing and stretching result in a film of the present invention that is soft and flexible at room temperature.

Examples 10-13

The same base copolyester of Example 1 was pre-dried at 65°C for 12 hours in a dehumidified dryer and compounded with various plasticizers, as listed in Table 4, using a 30-mm Werner-Pfleiderer 40:1 L/D co-rotating twin screw extruder. Without additional drying, the extruded compositions were placed on a Farrell two-roll mill at a set roll temperature of 150°C. After 10 minutes, the polyester composition was removed from the mill and fed through a 3-roll vertical calendering stack with roll temperatures ranging from 110-120°C to produce 0.254-mm thick films. Properties of the films, including Tg, Tm, and weight average molecular weight, are summarized as Illustrative Examples 10-13 in Table 4. Each example has a Tg below 23°C and a Tm between 150°C and 165°C.

DMTA curves of Examples 9 to 12 are presented in Figure 3. Each example displays a rubbery plateau that extends beyond 150°C. Thus,

films are formed with a Tg below 23°C and rubber-like properties up to 150°C. These results are totally unexpected.

Table 4

	Illustrative Examples				
	9	10	11	12	13
Base Copolyester (wt %)	70	70	70	70	70
Neopentyl glycol dibenzoate (wt%)		30			
Diethylene glycol dibenzoate (wt%)	30		30		
Butyl Benzyl Phthalate (wt%)				30	
Texanol Benzyl Phthalate (wt%)					30
Tg (°C) by DSC	-19	8	-17	-9	15
Tm (°C) by DSC	151	164	164	163	166
Weight Average Molecular Weight by GPC	39400	38900	38500	37800	39200

*Examples 10-13 contain 0.50 wt % of a fatty acid ester release additive.

Example 14

The base copolyester of Example 1 was compounded with glycerol tribenzoate at 15 weight percent and 30 weight percent. The Tg of the 30 weight percent polyester composition was 32°C. Utilizing the Fox equation for predicting the Tg of polymer/plasticizer and polymer/polymer mixtures, a 40 weight percent glycerol tribenzoate polyester composition is expected to produce a mixture with a Tg below 23°C.

Examples 15-19

10 A base copolyester, as shown for each Example 15-19 in Table 5, was pre-dried at 65°C for 12 hours in a dehumidified dryer and compounded with the plasticizer neopentyl glycol dibenzoate using a 30-mm Werner-Pfleiderer 40:1 L/D co-rotating twin screw extruder. Without additional drying, the extruded compositions were placed on a Farrell two-
15 roll mill at a set roll temperature of 150°C. After 10 minutes, the polyester composition was removed from the mill and fed through a 3-roll vertical calendering stack with roll temperatures ranging from 110-120°C to produce 0.254-mm thick films. Properties of the films, including Tg and Tm are summarized in Table 5. Examples 15-17 are illustrative examples of the
20 present invention. While Examples 18 and 19 have a Tg greater than 23°C, the addition of more plasticizer would lower the Tg. In particular, utilizing the Fox equation, the Tg of a polyester composition utilizing the same base copolyester of Example 19 is predicted to be below 23°C at 22 weight percent neopentyl glycol dibenzoate plasticizer.

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Table 5

	Examples				
	15	16	17	18	19
Base Copolyester (wt%)					
PETG 6763 ¹	35			42.5	85
Eastobond ²	35	35		42.5	
Embrace ³		35	70		
Neopentyl glycol dibenzoate (wt%)	30	30	30	15	15
Tg (°C) by DSC	10	5	12	30	39
Tm (°C) by DSC	154	166	170	170	172

¹copolyester of a diacid component of 100 mole % terephthalic acid and a glycol component of 31 mole % 1,4-cyclohexanedimethanol and 69 % percent ethylene glycol

²copolyester of a diacid component of 100 mole % terephthalic acid and a glycol component of 37 mole % diethylene glycol and 63 mole % ethylene glycol

³copolyester of a diacid component of 100 mole % terephthalic acid and a glycol component of 20 mole % 1,4-cyclohexanedimethanol, 9 mole % diethylene glycol and 71 mole % ethylene glycol